National Bureau of Standards

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DETROIT

TECHNOLOGY

New Data on Ductile Cast Iron

A RECENT study by Alexander I. Krynitsky and Harry Stern of the National Bureau of Standards substantially increases available information on the effects of different additives on the formation of nodular graphite. Because of its ductility and superior strength, nodular cast iron (having a nodular graphite structure) has excited considerable interest since its production was first described in 1948. Both cerium and magnesium, added in small amounts to the molten iron, have been used successfully to produce ductile cast iron. The cerium process was reported in 1948 by H. Morrogh and W. J. Williams, while in 1949 the International Nickel Company was granted patents for the magnesium method (U. S. Patents 2,485,760 and 2,485,761).

Additives investigated at NBS were magnesium, magnesite, iron sulfide, calcium, nickel-chromium-molybdenum, and boron. Cerium was not included, because published information on its application as a nodulizing agent was relatively complete when the study was begun. Besides the different additives, the investigation included such variables as composition, melting and pouring temperatures, and cooling rate.

In the NBS study, completely nodular graphite was obtained only in iron containing magnesium in excess of 0.03 percent. Two types of nodules were observed, radial and structureless, the structureless types frequently having a crystalline core. Results with magnesite, magnesia, and the other additives were essentially negative. However, oval or irregular patches of graphite—not true nodules—were observed in iron treated with magnesia, iron sulfide, and boron. Only a few nodules were observed in calcium-treated specimens, but this was probably because of the rather small amount of calcium retained; other investigators have reported 100-percent nodular graphite structures in irons having calcium contents higher than were obtained in this investigation.

The experimental method involved melting cast irons of various compositions in a high-frequency induction furnace. After the melt reached the desired temperature, the nodulizing agent under study was added. In general, the melt was next inoculated with 0.4-percent silicon and then cast in round bars. These were examined chemically, spectrochemically, photomicrographically, and for hardness.

Initial experiments with magnesium as the nodulizing agent used commercially pure magnesium. However, the violence of the reaction between pure magnesium and molten iron made close control of these early melts difficult. This method of addition was therefore abandoned, and the magnesium was supplied in the form of 80 Cu-20 Mg alloy.

The effect of cooling rate on microstructure was determined by casting wedge-shaped bars. The cooling rate, greatest near the apex of the wedge, was observed at intervals along the bar by means of thermocouples.

Rapid cooling favored nodule formation, but the effect of the cooling rate decreased with increase in magnesium content. No relation between nodule for-

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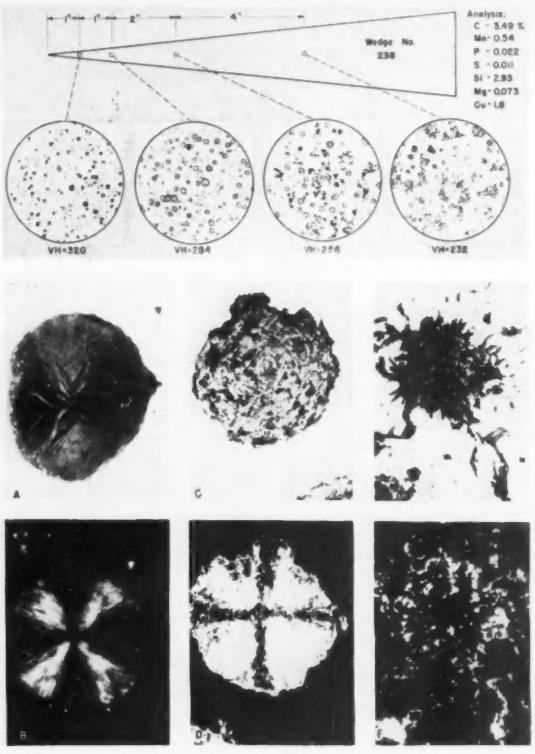

Above: as these photomicrographs show, faster cooling rates tended to produce a more nodular structure. The slower-cooling regions (right) show a flakier and less nodular graphite structure. (x35. VH-Vickers Hardness, 10-kilogram load.) Below: photomicrographs of graphite nodules (A, B, C, D) and patches (E, F) obtained in the recent study of nodular cast iron. Top row (A, C, E), under ordinary light; bottom row (B, D, F), under polarized light. Unetched, x250.

mation and pouring temperature or maximum heating temperature was observed. Results of the investigation support the belief that nodular graphite is formed in the melt during solidification, and that patches of graphite are produced after solidification by decomposition of carbides.

For further technical details, see Some experiments on producing nodular graphite in cast iron, *by A. I. Krinitsky and H. Stern, Foundry* (March 1952 and April 1952); *T. H. Wickenden, discussion of paper by H. Morrogh, Transactions of the American Foundrymen's Society* **56,** *88 (1948); A. L. DeSy, American Foundryman* **19,** *41 (Feb. 1951).*

TECHNICAL NEWS BULLETIN

U. S. DEPARTMENT OF COMMERCE

CHARLES SAWYER, *Secretary*

NATIONAL BUREAU OF STANDARDS
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Film Reader for Telemetered Information

A SEMIAUTOMATIC film-reader system recently developed at NBS for the Navy Bureau of Aeronautics facilitates the transcription of telemetered information recorded on 16-millimeter film. The new film reader was developed by F. H. Bayhi and M. L. Greenough of the Bureau's electronic instrumentation laboratory for operation in conjunction with the NBS parachute-telemetering system, in studying the behavior of military parachutes in test drops.

The NBS parachute-telemetering system is designed to transmit, from a parachute-borne radio transmitter to a ground station, information needed in studies of parachute performance—altitude, forces at various points, and similar data. The transmitter is modulated by a calibration signal and as many as seven measurement signals, selected in turn by a commutator device. On the ground, a receiver demodulates the transmitted information and feeds its to a cathode-ray tube. A single spot on the face of the tube moves up and down with the amplitude of the transmitted measurements, and its position is recorded continuously on film moving at constant speed. This gives a series of pulses on the film, with peaks of varying height, the height of each peak corresponding to a single measurement.

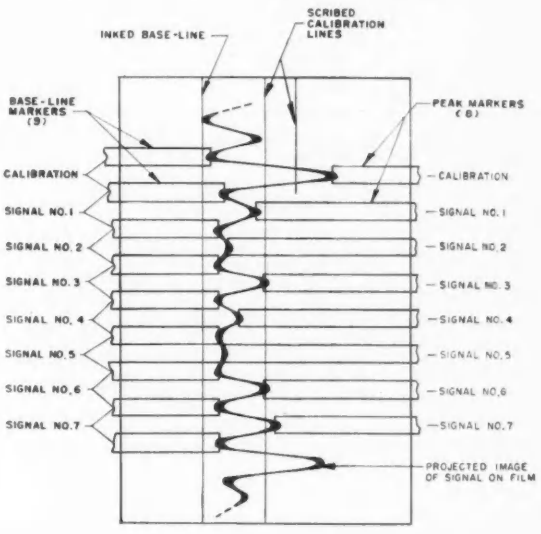
The observations are made at the rate of 6,000 sets (commutator revolutions) per minute, but are made continuously only during certain critical portions of

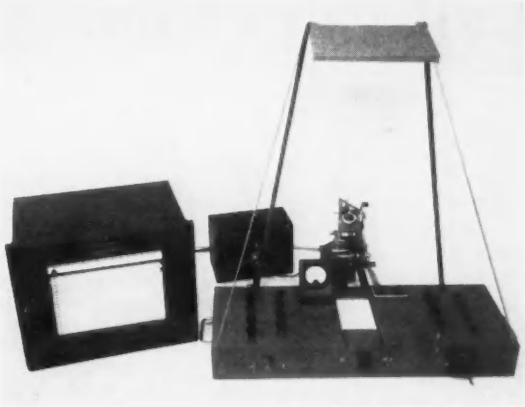
In the NBS film-reader system for transcribing telemetered information, magnified film images are projected onto a horizontal surface by means of a projector (rear) and reflector (top). Marker tips connected to 17 signal-measurement potentiometers (top of chassis) are adjusted to the signal-image peaks corresponding to the various information channels. When a button (front of chassis, just left of center knob) is pressed, the particular set of seven measurements is automatically transcribed to seven separate channels on the recorder chart (left). The small black cabinet (rear center) houses the power unit.

the parachute's fall. A typical film record of a single parachute drop depicts about 500 sets of measurements, made at successive intervals of time, each set consisting of a single observation of each of eight quantities (one set per commutator revolution). To make it useful, the data on the film must be replotted to give seven curves (the calibration signal is omitted) having a common time scale, each showing one of the measured quantities as a function of time. This is the problem that the NBS film-reader system was developed to handle.

In the new film-reader the enlarged image of a set of measurements is projected onto a horizontal surface; mechanical marker tips connected to potentiometers are manually adjusted to coincide with the peaks and base-line of the projected film image; and voltages derived from the potentiometers are fed to a modified commercial strip-chart recording instrument having an eight-channel input.

Seventeen of the signal-measurement potentiometers are used, one for each of the eight film-image peaks and one for the baseline point on either side of each peak. The potientiometers associated with each channel are connected in a network to which d-c voltage is supplied, and the arrangement is such as to give across one of the network summation resistors a d-c voltage proportional to the amplitude of the corresponding signal image on the film.





After setting the marker tips on the image of the first set of eight measurements, the operator adjusts the sensitivity of the system so that the calibration signal is set at a standard level. He then presses a button that puts the recorder through an automatic printing cycle. In each cycle the recorder selects one after another of the eight measurement channels and—as soon as balance is achieved—prints the measured value on special chart paper marked off into seven equal-width strips. Instead of the regular slow-speed continuous chart-drive, the driving mechanism is arranged to advance the chart approximately 0.005 inch each time the recorder prints.

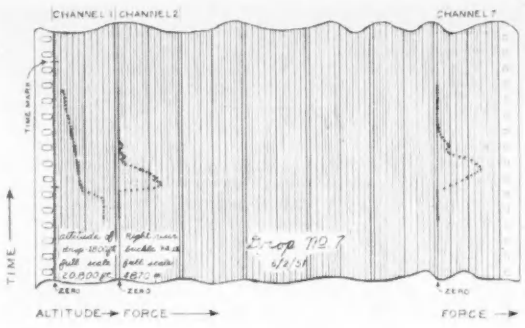
After printing a value for each channel, the recorder stops automatically. While the recorder is printing, the operator advances the film to the next set of measurements. He now again alines the marker tips connected to the signal-measurement potentiometers and presses the button to start the recorder through a new cycle. The process is repeated until all sets of measurements for the particular parachute drop have been thus transcribed from the film to the chart.

To make the recorder print properly in the seven separate strips on the recorder chart, separate bias voltages are inserted automatically for channels 2 through 7. No bias is needed for channel 1, as its zero point is also the zero point of the recorder pen.

Telemetered film records of a great many parachute drops must be studied in the research program for which the NBS parachute-telemetering system was developed, and the new film reader makes possible important savings of time as well as greater freedom from error in transcription. In the past, an operator using a simple microfilm viewer and scale has required about 3 days to take from the film strip the data for a single parachute drop, and the data has then had to be plotted

Typical film image of a single set of seven measurements, plus calibration signal, projected on film-reader screen. The entire film record of a single parachute drop consists of about 500 such sets of measurements made at successive intervals of time.

Sample recorder chart onto which measurements for a parachute drop have been transcribed from 16-millimeter film. (Not all the data on the film were transcribed in preparing the sample.)



by hand. Using the new film reader, the entire operation is expected to take only 3 or 4 hours. Since no mental interpolation is required, operator fatigue is also reduced. With clear film images and careful alinement of the marker tips, total error is well under 5 percent. Since variation between individual parachute drops is considerably greater, the errors in the film reader are relatively small.

Electronic Peak-Reading Kilovoltmeter

AN INSTRUMENT that rapidly and accurately measures the high voltages associated with medical X-ray equipment has recently been developed by R. E. Brueckmann of the Bureau. The unit is designed to indicate directly peak voltages between 30,000 and 125,000 volts and thus replaces the sphere gap method, which is ordinarily used to measure high voltages in diagnostic X-ray apparatus. The kilovoltmeter is especially useful for measuring voltages during short exposures with provisions to prevent the recording of initial surges.

The voltages used in medical X-ray equipment must be variable over a wide range in order to compensate for the different thicknesses of various parts of the body. Present apparatus is designed to provide voltages adjustable from 35-kilovolt peak to 120-kilovolt peak in steps of 2-kilovolt peak or less. Blackening of the film is approximately proportional to the peak voltage across the X-ray tube; thus, it is necessary to calibrate the machines accurately if reproducible results are to be obtained.

Diagnostic exposure to the X-rays must necessarily be short to prevent blurring of the radiograph due to motion of the subject. Exposures generally range from $\frac{1}{60}$ second to 1 or more seconds, necessitating tube currents as high as 500 milliamperes to produce the desired film blackening. At these high currents, the anode of the X-ray tube is heated so severely that it is impossible to make the longer exposures necessary for calibration.

The sphere gap is generally used for measuring the high potentials across X-ray tubes. Two different operating methods are available. In the more accurate method, the spheres are pulled together slowly until voltage breakdown occurs between them. The peak voltage may then be read on a calibrated scale that is actuated by the sphere separation. However, it is impossible to employ this method for exposure times much shorter than 2 seconds because of the slowness with which the spheres must be brought together in order to note accurately the breakdown separation.

In the second method, the sphere gap is set for a voltage somewhat higher than anticipated and a short exposure is made. If the gap does not break down, the spacing is decreased slightly and another exposure is made. This process is repeated until the setting at which the gap breaks down is reached. In addition to being time-consuming, this method will be in error if the voltage to be measured surges above its steady-state value during the first few cycles of the exposure.

If a sphere gap is employed in calibrating self-rectified equipment, in which alternating current is applied to the X-ray tube, the voltage indicated by the sphere gap will be the inverse voltage across the X-ray tube. Because of the regulation of the high-voltage transformer, this voltage will be higher than the voltage across the tube during its conducting half-cycle. A bulky high-voltage rectifier tube and its associated filament transformer must be used in series with the sphere gap to block the inverse voltage and enable the sphere gap to measure the smaller forward voltage.

Series resistance must be included in the sphere gap circuit to limit the current when the gap breaks down. However, to obtain accurate results the resistance should not exceed 1 ohm per volt. The resulting arc current of 1 ampere usually overloads the equipment under test. For example, some dental X-ray units have a maximum current rating as low as 15 milliamperes.

The NBS peak-reading kilovoltmeter overcomes all of these shortcomings of the sphere gap. It requires no manipulation during the exposure and retains its reading until reset. Peak voltages can be measured during exposures as short as $\frac{1}{60}$ second. The unit also includes circuits that can, if desired, prevent the initial surge from being recorded and permits the reading of either the forward or inverse voltage on self-rectified equipment. During normal operation, the meter draws a maximum current of 1.25 milliamperes from the equipment being calibrated.

In principle, the kilovoltmeter operates as follows: A type 2D21 thyratron tube is used as the high-voltage detector. The critical bias on the tube is about -3 volts at a plate potential of about 150 volts. If, for

example, the bias voltage is 103 volts, the thyratron will fire when the voltage drop across two 50,000-ohm resistors between the bias cell and ground and the cathode and ground reaches 100 volts. These two resistors form part of a two-section voltage dividing network across the X-ray tube. Because the ratio between the sections of the voltage divider is very nearly 1,000 to 1, the metering circuit will respond when the peak voltage across the X-ray tube reaches 100 kilovolts. Hence, any desired kilovoltage may be measured by suitably adjusting the bias voltage.

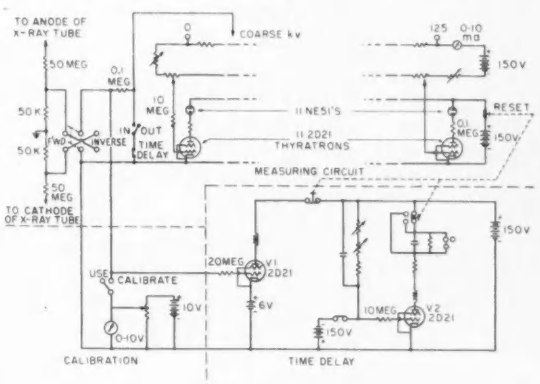
The actual circuit of the NBS kilovoltmeter consists of eleven 2D21 thyratrons each having an indicating neon light in its plate circuit. The grids of the thyratrons are biased in approximately 1-volt increments by potentiometers inserted into each grid circuit. Twenty series-connected resistors are connected to a 22 position selector switch so that a voltage adjustable from 30 to 125 volts in 5-volt steps may be added to the bias on each tube. These resistors and the grid potentiometers constitute a voltage-dividing network, across which 150-volt d-c is applied. It is thus possible to preset the instrument to read the kilovoltage within any desired 10-kilovolt range, the reading being the sum of the setting on the coarse kv- (kilovolt) selector switch and the number indicated by the last activated neon lamp. A reversing switch between the voltage divider and the kv-selector switch permits measurement of either the positive or negative peaks of the voltage applied to the potential divider and, hence, either the useful or inverse kilovoltage.

A calibrating circuit is included in the instrument for setting the bias voltages of the 11 thyratrons. When the "use-calibrate" switch is closed (applying the calibrating voltage to the measuring circuit) and the coarse kv-selector switch is set at zero, any desired voltage from 0 to 10 volts may be applied to the thyratron grids through their biasing resistors. This voltage is increased slowly and the bias potentiometers set until at each integral voltage the corresponding thyratron fires.

A calibration is also made to adjust the instrument to high-resistance voltage dividers with ratios differing slightly from 1000:1. This is done by initially comparing the readings of the instrument with those of a sphere gap and adjusting the current through the resistors on the coarse kv-selector switch by means of an additional potentiometer (in series with the grid potentiometer) until the instrument agrees with the sphere-gap readings. A milliammeter included in the circuit indicates the current, and after the correct value has been determined, the instrument may be calibrated thereafter merely by adjusting to the proper current value.

The time-delay circuit, incorporated to prevent recording of the starting surge, includes two thyratrons and two relays. The two thyratrons are initially nonconducting when the time delay is switched into the circuit. When the X-ray exposure is made, voltage appears on the grid of the first tube, causing it to fire and to energize a relay in its plate circuit. A relay contact in the grid circuit of the second thyratron opens and allows the grid voltage to rise to its firing value at a rate determined by an R-C circuit. The tube fires, energizing the second relay, which allows the measuring circuit to record the peak voltage under steady-state conditions. A third switch prevents the recording of any surge occurring at the end of an exposure. When it is open, the second relay remains open only during the charging time of a resistor-condenser network in this particular circuit and closes before any final surge occurs. The time constant of the condenser and its associated resistances is about $\frac{1}{10}$ second.

The NBS peak-reading kilovoltmeter is mounted on a 10- by 14- by 3-inch chassis and placed in a small cabinet. The calibrating controls and meters, which are seldom used, are located on the top of the chassis and are reached by opening the top of the cabinet.



Left: Schematic diagram of the NBS electronic peak-reading kilovoltmeter. The measuring circuit includes 11–2D21 thyratron tubes and 11–NE51 neon indicating lamps. A time-delay circuit composed of a pair of thyratrons, two relays, and suitable R–C time delays may be switched into the operating circuit if desired. Provisions are also made for calibration of the instrument. Right: Front view of the electronic peak-reading kilovoltmeter. A coarse kv selector presets the instrument to read within any 10 kilovolt-peak range. Neon lamps in each of 11 thyratron plate circuits indicate which tube is conducting and hence affords a finer kilovolt measurement scale.

Film-Rupture Mechanism of Stress Corrosion

STRESS-CORROSION cracking, caused by the combined action of stress and corrosion, can be responsible for the spontaneous service failure of objects ranging from brass cartridge cases to stainless-steel coffee urns. Although the problem is an important one, much remains to be learned about the mechanism of stress-corrosion cracking. A continuing investigation at the Bureau, conducted by Hugh L. Logan of the Corrosion Section, now provides new data on some of the mechanical and electrochemical phenomena involved.

Corrosion is generally considered to be an electrochemical phenomenon, involving the flow of minute electrical currents between areas of different potential. When most metals are exposed to ordinary atmospheres, a thin oxide film is quickly formed that tends to protect the metal from further corrosion. According to the most generally accepted theory,[1] which the NBS study tends to confirm, stress-corrosion cracking starts with a scratch or break in this protective film. When the protective film is broken through, the freshly exposed metal is more anodic (more negative) than the surrounding film-covered surface, and if moisture is present an electric current flows that causes the metal to be removed from the exposed area.

According to Mears, Brown, and Dix, "if attack penetrates preferentially along a narrow path, it would appear axiomatic that a component of tensile stress normal to the path would create a stress concentration at the base of the localized corroded path. The deeper the attack and the smaller the radius at the base of the path, the greater would be the stress concentrations. Such a condition would act to pull the metal apart along these more or less continuous localized paths. At sufficient concentration of stress, the metal might start to tear apart by mechanical action . . . the tearing action described above would expose fresh metal, unprotected by films, to the action of the corrosion environment. Because this freshly exposed metal is more anodic, an increase in current flow from the base of the localized path to the unaffected surface would be expected, and hence there would be an acceleration of corrosion. Further corrosion would result in further tearing of the metal, and as a result, increased rate of penetration would occur because of the mutual effect of the corrosion environment and the tensile stress." [1]

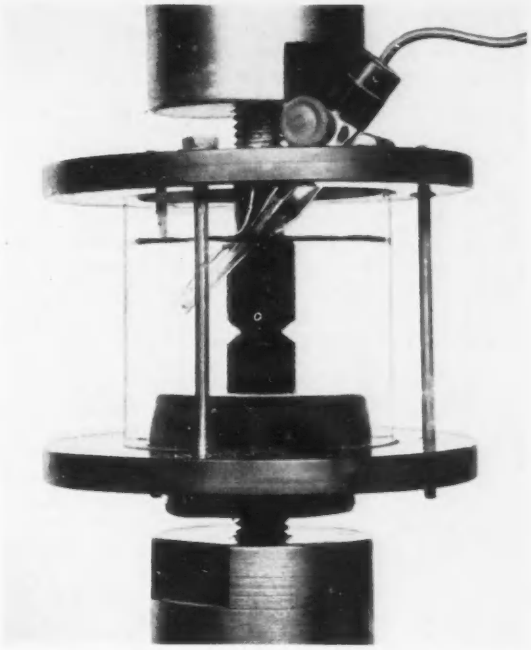
To get a better understanding of the forces at work in stress corrosion, the NBS investigators measured electrochemical potentials of five alloys in normal film-covered and film-free conditions, both stressed and unstressed (see table 1). Specimens were immersed in a suitable electrolyte, and potentials were determined using a calomel reference electrode of the saturated KCl type.

Studied were an aluminum alloy, a magnesium alloy, two brasses, a low-carbon steel, and a stainless steel. Potentials were measured first for unstressed specimens having normal thin oxide films resulting from ordinary atmospheric exposure. Potentials were then measured for the same specimens after the filmed surfaces had been removed by abrasion with metallographic polishing paper. The abrading was done in an inert-gas (argon) atmosphere in a dry box, and the potentials were measured without removing the abraded specimens from this atmosphere. Each metal studied was more cathodic (more positive) in the normal film-coated form than in the abraded form, by amounts ranging from approximately 0.12 to 0.76 volt.

The electrochemical solution potentials of the same alloys, in the normal film-covered conditions, were then measured with stress applied. It was postulated that, when tension is initially applied to a metal, small breaks develop in the protective film, giving corrosion a chance to get started before a fresh film can form. If the electrochemical potential of the unprotected area alone could be measured, it would presumably be roughly the same as that of a film-free surface. Measurement of change of potential with stress has been attempted before, but the attempts have generally been unsuccessful.

[1] Proposed by R. B. Mears, R. H. Brown, and E. H. Dix, Jr., Symposium on Stress Corrosion Cracking of Metals, Am. Soc. Testing Mat. and Am. Inst. Mining Met. Engrs., p. 323 (1944).

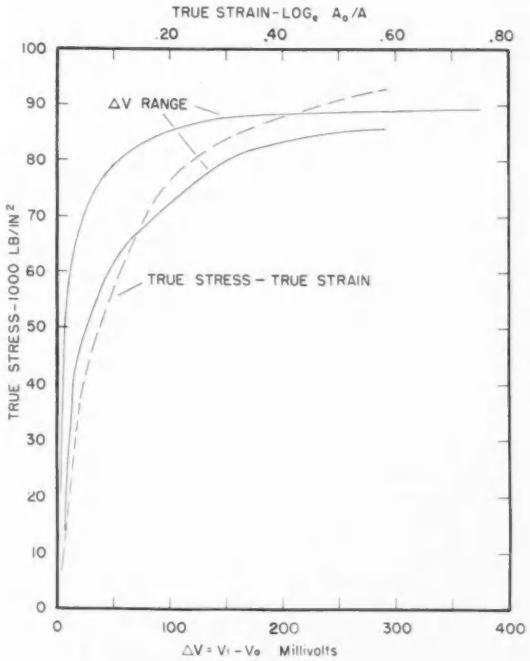
Metal specimens were abraded in an inert (argon) atmosphere to remove the air-formed film that is ordinarily present. Using the equipment shown, the operator works through rubber gloves to abrade specimens inside the argon-filled-and-sealed enclosure. Electrochemical solution potentials of the film-free specimens are then measured without removing the specimens from the air-free enclosure.



To measure the change of electrochemical solution potential with stress, a notched metal specimen (center) was placed in a suitable cell filled with an electrolyte (usually potassium choride). The potential between the specimen and an immersed electrode (entering the solution at an angle) was measured as a tensile stress was applied to the specimen. The specimens were coated with nonconducting waterproof lacquer, a thin strip of which was removed at the base of the notch to expose a small maximum-stress area of metal.

The difficulty of measurement in the past has arisen because the total area of conducting-though-film-covered surface of the specimen has been very much larger than the areas in which the film is broken under stress. When a calomel electrode is placed in an electrolyte in which the test specimen is immersed, the potential readings obtained represent essentially the potential of the relatively very large film-covered surface; the film-free surface is so small by comparison that it may not even be possible to detect any change of potential when the specimen is stressed.

At NBS this measurement problem was solved by coating an entire notched specimen with a nonconducting waterproof lacquer, then using a razor blade to remove a narrow band of lacquer at the root of the notch. With specimens thus pepared, the only potential being measured was that of the narrow band of metal at the root of the notch where the stress was concentrated. With fairly rapid application of stress the film-free area then became a substantial fraction of the total nonlacquer-covered area, and the potential became more negative as the stress was increased. If the stress was held constant for some time, the solution potential generally reverted quickly to that of the unstressed metal. If the stress was increased rapidly, however, the measured potential tended to approximate that of a film-free surface as the point of fracture was reached.



Change of potential with stress (solid lines) and true stress-true strain relations (dotted line) for 61% Cu, 36% Zn, 3% Pb for brass, as found in the NBS stress-corrosion study.

For further technical details, see Film-rupture mechanism of stress corrosion, *by Hugh L. Logan, J. Research NBS* **48**, (Feb. 1952) RP2291.

TABLE 1. *Electrochemical solution potentials,[a] and maximum change in potential with stress, for several alloys*

Alloy	Electrolyte	Electrochemical solution potentials, unstressed specimens		Maximum change in potential with stress
		Normal film	Film-free	
		Volts	*Volts*	*Volts*
24S-T4 Aluminum alloy	KCl (saturated)	−0.67	−1.43	0.610
70% Cu-30% Zn brass	5% NH_4OH+5% $(NH_4)_2CO_3$	−.47	−0.96	.700
61% Cu-36% Zn-3% Pb brass	do	−.39	−.98	.510
AZ31 magnesium alloy	3.5% NaCl+2% K_2CrO_4	−1.51	−1.645	.240
Low-carbon steel	5% NH_4NO_3	−0.60	−0.72	.160
Type 302 stainless steel	KCl (saturated)	−.28	−.78	.315

[a] With respect to calomel reference electrode of saturated KCl type.

Position-Labeled adi

Carb Sugar
Nowailable
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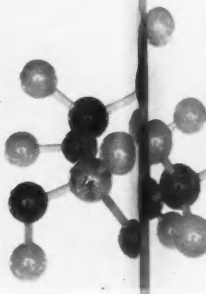
SUGARS and sugar derivatives having radioactive carbon atoms located in specific positions within the molecule have been prepared by the National Bureau of Standards for the first time in good yield and high activity. Identical with ordinary sugars except for the radioactive atom of carbon 14, the specifically labeled sugars will be a distinct aid to research workers in biology, bacteriology, chemistry, and medicine, enabling them to trace a single carbon atom through an entire series of complex chemical reactions. Availability of these materials should thus provide the key to such problems as the role of lactose in nutrition, the mechanisms by which bacterial cellulose is produced from sugars, and the action of enzymes in living organisms. Development of practicable procedures for synthesizing the sugars is the result of a broad program on radioactive carbohydrates now being conducted by Dr. H. S. Isbell and associates of the NBS staff under the sponsorship of the Atomic Energy Commission.

Since carbon 14 became available near the end of World War II, it has made possible new isotopic tracer techniques in the study of plant and animal metabolisms, the polymerization of organic molecules, and many other complex organic processes. Its utility as a tracer is due in large part to the ease with which it can be detected in small concentrations and the fact that its chemical behavior does not differ in any important way from that of ordinary carbon. Thus, a very small quantity of carbon 14 can be substituted for ordinary carbon in a carbohydrate material such as glucose, and the biochemical reactions and interconversions it undergoes in a living animal can be followed by means of suitable procedures for detection of radioactivity.

Until now, however, application of labeled carbon to carbohydrate metabolism studies has been largely restricted for lack of sugars containing radiocarbon. Although some labeled sugars have previously been obtained by workers in other laboratories, in most of these sugars the carbon-14 atoms replaced the normal atoms in the molecule in a random manner, making it impossible to determine which particular atom entered a reaction. Introduction of the labeled carbon atom at a specific point within the sugar molecule was not only a difficult and intricate process, but was also prohibitively expensive. Yields were less than 10 percent of recoverable radioactive material, and in most cases the products were only weakly redioactive. In view of the urgent need for position-labeled sugars in biochemical research, the Bureau undertook to develop satisfactory methods for producing these materials in sufficient quantity to meet the needs of research laboratories. Efforts were made to obtain increased yields and greater simplicity in methods of synthesis. To date, 13 different position-labeled sugars or sugar derivatives have been prepared by NBS. Some of these



Left: The relatively weak beta radiation emitted by the ca in sa on a radiation counter before the samples are weighed and ted. ing the labeled carbon 14 atom in position number one of ton cha represented by black spheres. Right: To remove water fr radioac vacuum drying technique that avoids dispersal of the acti

The lactone containing carbon 14 is reduced to the corresponding radioactive sugar by adding sodium amalgam slowly through a side tube while the buffered lactone solution is stirred mechanically in an ice bath. The effective application of this step of the cyanohydrin synthesis to the semimicro procedure required in working with carbon 14 was largely due to the selection of suitable buffer materials and the development of an amalgam that can be handled in small quantities.

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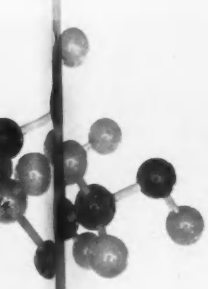
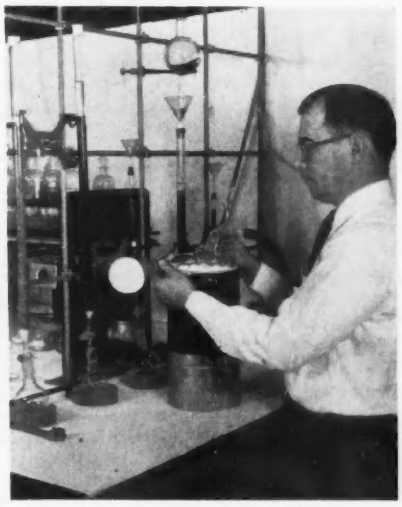




the ca in samples of the NBS position-labeled sugars is measured ed and ated. Center: Atomic model of the glucose molecule show- ne of bon chain. The remaining carbon atoms of the molecule are ater fr radioactive sugar solutions, the Bureau employs a convenient ne acti

compounds are already available for limited distribution; others soon will be made available.

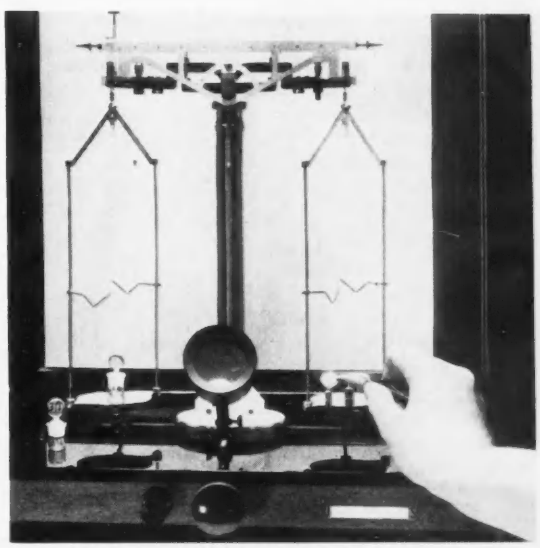
Work began with an extensive study of the cyanohydrin synthesis, a method that has been used for many years in NBS laboratories for the preparation of rare sugars. Because of the scarcity and high cost of the C^{14}-containing cyanide used in the synthesis, it was necessary to work with semimicro quantities. It seemed probable that the low yields obtained by previous investigators were due in part to the use of macro procedures on a semimicro scale. Each step was therefore modified for use at the millimole level, and means were found to improve nearly all the steps in the process in other ways.

In this application of the cyanohydrin synthesis, the labeled sugar is in most cases prepared by removing a carbon atom from a natural sugar and replacing it with carbon 14. Thus, for example, in the preparation of labeled glucose, the 6-carbon sugar, glucose, is first oxidized to yield the 5-carbon sugar, D-arabinose. Reaction of the D-arabinose with sodium cyanide containing carbon 14 yields two organic cyanides (cyanohydrins) that are epimers, that is, their molecules differ only in the spatial arrangement of the atoms attached to the second carbon in the chain. Hydrolysis of the cyanohydrin epimers gives a mixture of the epimeric acids, gluconic acid and mannonic acid. The epimeric acids are separated, and the gluconic acid is first converted to the corresponding lactone (the inner ester of the acid) and then reduced to the labeled glucose. Similarly, the lactonization and reduction of the mannonic epimer yields mannose, a sugar that is an epimer of glucose.

For most tracer applications, labeled glucose is desired rather than labeled mannose. However, in the classical cyanohydrin synthesis, the cyanohydrin having the mannose configuration greatly predominates over the one having the glucose configuration. In the NBS investigation it was found that the reaction of D-arabinose with hydrogen cyanide can be controlled by the presence or absence of general acid catalysts so that either of the two products can be made to predominate. This improvement makes possible the production of the desired gluconic cyanohydrin in high yield and thus increases the yield of glucose.

It was also found that the conditions under which previous workers had carried out the hydrolysis of the cyanohydrins—long refluxing on a steam bath with barium hydroxide or calcium hydroxide—had been so drastic as to cause deterioration of the products. The NBS investigators discovered that this hydrolysis takes place satisfactorily under much milder conditions and is conveniently effected by heating the cyanohydrin in sodium carbonate solution at 60° C for several hours with aeration and concentration of the solution. In this way, the decomposition that occurs at higher temperatures was avoided.

For the separation of the epimeric acids in the glucose-mannose synthesis, advantage was taken of the fact that one of the lactones of mannonic acid crystallizes more readily than either of the lactones of gluconic acid.



After final crystallization, the NBS position-labeled sugars are placed in the bottom of small weighing bottles in amounts of 10 to 100 milligrams, and the exact weight of each sample is determined. The samples are then distributed in the weighing bottles to other laboratories.

Before final crystallization, the NBS radioactive sugars are filtered through a specially designed semimicro filtration apparatus to remove any possible foreign matter. Use of the compact, all-glass device results in a minimum loss of radioactive material.

and that gluconic acid forms a crystalline barium salt whereas mannonic acid does not. Thus, in preparations designed primarily for the production of mannose, mannonic lactone was crystallized directly from the mixture of crude epimeric lactones; in preparations designed for the production of glucose, gluconic acid was separated first in the form of the barium salt. Similar procedures were worked out in the preparation of the other sugars.

Perhaps the most significant improvement was in the final step of the series, the reduction of the sugar acid lactone to the sugar. This conversion is ordinarily accomplished by the action of sodium amalgam in acid solution. The efficiency of the reaction was increased at NBS by the development of an amalgam of uniform composition that can be conveniently handled in small quantities without undue contamination from the atmosphere. In conventional methods on a macro scale, the acidity of the reaction mixture is maintained by adding sulfuric acid drop by drop to the solution as the reaction proceeds. Obviously, this technique cannot be used with very small quantities. Thus, in adapting the macro-scale procedures for use with a few milligrams of material, it was necessary to devise a means for automatically maintaining the desired acidity. It was found that this can be done by having certain difficultly soluble organic acids present in the reaction mixture. As the reaction proceeds, the difficultly soluble acid goes into solution and neutralizes the alkali as it is formed. Studies of several hundred reaction mixtures showed that bensoic acid and sodium acid oxalate are highly satisfactory internal neutralizing agents.

Chemical procedures were also devised for removing the neutralizers from the sugar solutions. Ion-exchange resins are used to de-ionize the aqueous solution that remains after the sodium-amalgam reduction, and the sugars are finally crystallized from alcoholic solutions. About half of the yield of sugar is crystallized directly; the rest is obtained by the so-called carrier technique. In this procedure nonradioactive sugar is dissolved in the residual sirup and allowed to crystallize with the radioactive modification. By successive additions of the normal sugar and recrystallization, nearly all of the radioactive sugar is ultimately extracted from the solution.

By use of the neutralizing agents and the improved procedures, it was found possible to convert as little as 18 milligrams of glucono-Δ-lactone to glucose in 85-percent yield. Either D-glucose-1-C^{14} (D-glucose having C^{14} in the No. 1 position of the six-carbon chain) or D-mannose-1-C^{14} can be obtained in over-all yields of 50 percent, with a total radiochemical yield of D-glucose and D-mannose of at least 60 percent.

In addition to labeled D-glucose and D-mannose, the following 1-C^{14}-labeled sugars have been prepared and are available for distribution in limited quantity: D-arabinose, D-ribose, D-galactose, and lactose. Other materials available, or shortly to be made available, are mannitol-1, 6-C^{14}, D-fructose-1, 6-C^{14}, D-arabinose-5-C^{14}, D-glucose-6-C^{14}, D-glucose-2-C^{14}, sorbitol-6-C^{24}, and L-sorbose-6-C^{14}. The sugars are usually supplied at an activity level of about one microcurie per milligram. Development work continues at NBS in this field, and other synthetic methods are being worked out that will provide additional position-labeled sugars and sugar derivatives.

For further technical details, see Synthesis of D-glucose-1-C^{14} and D-mannose-1-C^{14} *by H. S. Isbell, J. V. Karabinos, H. L. Frush, N. B. Holt, and A. Schwebel, J. Research NBS* **48** (March 1952) RP2301.

Effect of Melamine Resin on Chemical Tests of Paper

MELAMINE-FORMALDEHYDE resin is one of the many synthetic materials used in the manufacture of plastic products. The adaptation of this resin to paper technology has resulted in the improvement of many important properties of paper including dimensional stability, freedom from linting, reduced curl, and the development of high wet-strength without great reduction in absorbency. With the increasing use of melamine resin in paper and paper products has come the need for data on the effects of the presence of the resin on chemical tests applied to paper, in order that the results of such tests may be correctly interpreted. Accordingly, a study of some of the widely used chemical tests of paper was undertaken at the Bureau by

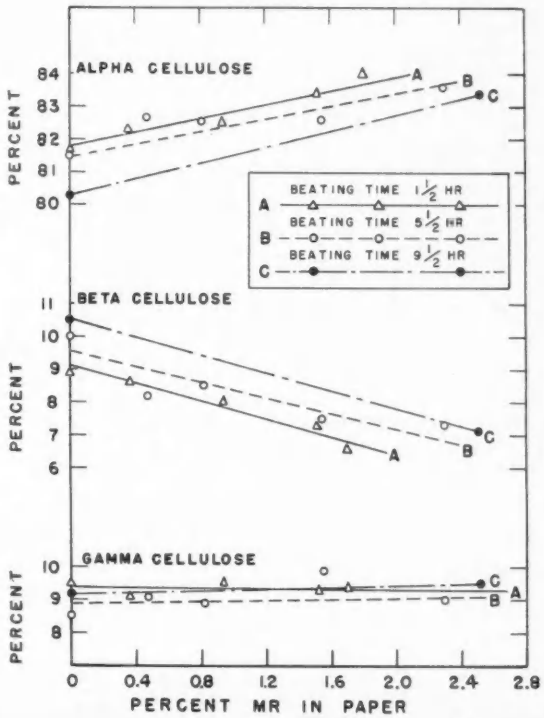
Apparatus used by NBS to determine the effect of melamine resin on the viscosity of solutions of paper in cuprammonium hydroxide. Viscosity is one of the chemical tests that are affected by the presence of melamine resin in paper.

William K. Wilson, Jack L. Harvey, and Alice A. Padgett. The work included the determinations of alpha-cellulose, copper number, rosin content, pH, and cuprammonium disperse viscosity.

It was found that the addition of melamine resin in the manufacture of a paper usually increases the analytical alpha-cellulose value of the paper. The alpha-cellulose value, which is an indication of cellulose quality and of a paper's resistance to deterioration, is, analytically, the fraction of the total cellulose that is insoluble in sodium hydroxide under standard test conditions.

The determination of rosin, which includes both natural resins and any rosin soaps added to impart resistance to water penetration, is unaffected by the presence of melamine resin in a paper. The copper number, on the other hand, is reduced by melamine resin; this represents an improvement, since high copper numbers are indicative of low-quality cellulose.

The NBS investigation also revealed that melamine resin undergoes an alkaline hydrolysis in hot-water solution. Papermaker's alum (aluminum sulfate), used extensively to precipitate rosin soaps and to adjust pH in the manufacture of paper, is known to undergo an acid hydrolysis in hot-water solution. Since the ph of paper—another indication of the stability or permanence of paper—is often measured on the hot-water extract of the paper, it is apparent that this value will depend on the relative amounts of alum and melamine resin present.



Graphic representation of the effect of melamine resin (MR) in paper on the alpha, beta, and gamma cellulose values. Data are shown for several lithographic offset papers containing 75% bleached sulfite and 25% bleached soda and beaten, 1½, 5½, and 9½ hours.

The cuprammonium disperse viscosity of cellulose is related to the length of the cellulose chains (molecules) and this is, in turn, related to the quality of the cellulose. Measurement of viscosity of papers is made on a solution of the paper in a suitable solvent, in this case cuprammonium hydroxide. In measuring the cuprammonium viscosity of papers with and without melamine resin, it was found that the resin renders high-quality papers only partially soluble in the reagent at 0.5 percent concentration. For this reason viscosity measurements lose their meaning.

In addition to the chemical tests mentioned, the effect of melamine resin on the heat stability test, used to compare the relative stabilities of papers to natural aging, was examined. Results indicated that melamine resin tends to stabilize papers, as measured by the changes occurring in alpha-cellulose and copper number on accelerated aging.

In summary, the presence of melamine resin in a paper, in addition to imparting special properties, appears to produce a slight improvement in the quality of the cellulose and in the stability of the paper. Whether such improvements are related to the true permanence of a paper—its resistance to natural aging—is yet to be determined.

For further technical details see Effect of melamine resin on chemical tests of paper *by William K. Wilson, Jack L. Harvey, and Alice A. Padgett, TAPPI* **34**, No. 9 (Sept. 1951).

Oil Flow in Plain Journal Bearings

A SIMPLIFED method of analysis for the rate of oil flow in plain journal bearings has been developed by S. A. McKee, head of the NBS engines and lubrication laboratory. This problem is important to bearing design and operation; an adequate oil flow is essential to insure not only the maintenance of a load-carrying oil film, but also the disposal of frictional heat developed in the bearing.

The new method, developed from data obtained on the NBS four-bearing friction machine in conjunction with the NBS-NACA lubrication research program, indicates that flow of oil from the ends of plain journal bearings fed through an oil hole, an axial groove on the unloaded side, or a circumferential groove may be affected by two factors. One results from the oil-feed pressure, and the other from the hydrodynamic-film pressure supporting the load. In the case of a bearing with a circumferential groove, the flow due to the hydrodynamic-film pressure is negligible in comparison with that due to the oil-feed pressure. For the other two types of bearings, however, both causes produce appreciable flow.

In the present work, analytical simplicity is achieved by postulating that the rate of oil flow, Q, is made up of two components, as follows:

$$Q = Q' + Q'' \qquad (1)$$

where Q' is the flow rate caused by the oil-feed pressure, and Q'' is the flow rate produced by the hydrodynamic-film pressure supporting the load. It is further recognized that, for any given type of oil-feed design, the two oil-flow components are related to bearing dimensions and operating variables. This relationship may be expressed by the following dimensionless equations:

$$\frac{Q'\mu}{pC^3} = \psi_1\left(\frac{D}{C}, \frac{C}{L}, \frac{\mu N}{P}\right) \qquad (2)$$

$$\frac{Q''\mu}{PC^3} = \psi_2\left(\frac{D}{C}, \frac{C}{L}, \frac{\mu N}{P}\right) \qquad (3)$$

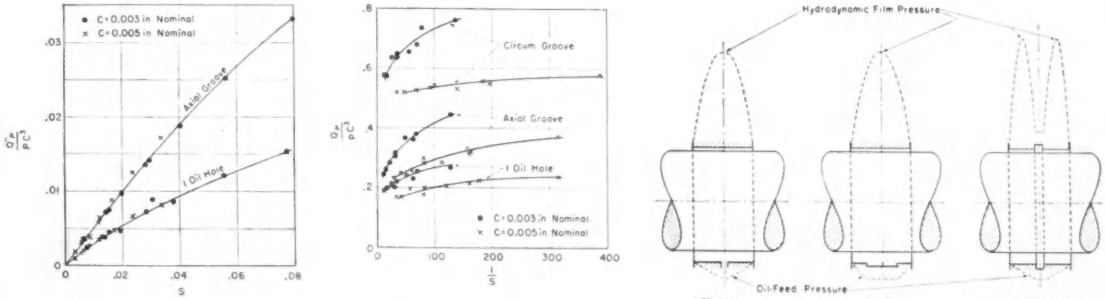
where μ = absolute viscosity of the lubricant at atmospheric pressure and bearing temperature, p = oil-feed pressure, P = load per unit projected bearing area, N = speed of journal, D = journal diameter, L = bearing length, and C = diametral bearing clearance.

As indicated above, the functions ψ_1 and ψ_2 depend upon the oil-feed design of the bearing. These have been determined experimentally for three basic designs: (1) one oil hole on the unloaded side of the bearing, (2) an axial groove on the unloaded side of the bearing, and (3) a circumferential groove. The results may be shown graphically by plotting the parameter containing Q'' against the Sommerfeld number, $S = (\mu N/P)(D/C)^2$, and by plotting the parameter containing Q' against the reciprocal of the Sommerfeld number.

In obtaining the above information, it is necessary to separate the observed total oil flow, Q, into its components Q' and Q''. For this purpose, a simple method was used. Briefly, the separation is done by plotting $Q\mu$ against p for constant values of $\mu N/P$. On such a plot, the data for each value of $\mu N/P$ fall on a straight line, the slope of which is equal to $Q'\mu/p$, while the intercept at $p = 0$ equals $Q''\mu$.

It is of interest to note that in the case of a bearing with a circumferential groove, the oil flow due to hydrodynamic-film pressure is negligible. However, for the other two oil-feed arrangements, this component is quite significant.

The good correlation of the parameter $Q''\mu/PC^3$ with Sommerfeld number, at different bearing clearances, is noteworthy. The differences obtained with



Recent data obtained at the Bureau indicate that the rate of oil flow in journal bearings is affected by the oil-feed and hydrodynamic-film pressure which are, in turn, related to the bearing design and operation. The effects of design can be shown by plotting the parameter containing Q'' ($Q\mu''/PC^3$) against the Sommerfeld number $S = [(\mu N/P)(D/C)]$, A, and the parameter containing Q' ($Q'\mu/pC^3$) against the reciprocal of the Sommerfeld number, B. The pressure distributions for each design of oil feed (1 oil hole, axial groove, and circumferential groove) are shown in C.

bearings of different clearances when plotting $Q'\mu/pC^2$ against the reciprocal of Sommerfeld number are attributed to bearing out-of-roundness caused chiefly by deformations under lead.

For further technical details see, Oil flow in plain journal bearings *by S. A. McKee, Paper No. 51–A–34, presented at ASME Annual Meeting, Atlantic City, N. J., November 25 to 30, 1951, and scheduled for publication by ASME.*

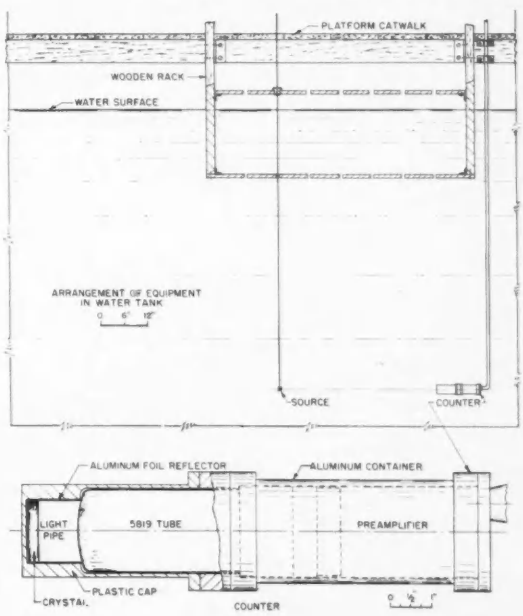
Penetration of Gamma-Rays

ACCOMPANYING the increased use of radioactive materials in industrial research and medicine is a growing concern for the harm radiations from these materials can inflict on personnel. To aid in reducing these dangers to a minimum, the National Bureau of Standards, in cooperation with the Office of Naval Research and the Atomic Energy Commission, has been conducting a theoretical and experimental investigation of radiation-shielding devices. This particular program is devoted largely to studies of the distance radiations travel from their sources and the transformations they undergo during the process. The experimental phases of the work are designed to yield information that is essentially general in nature but which can be readily adapted to specific problems. Whenever possible, the experiments are carried out on a small scale or on a model. In this way, a wide variety of investigations can be made of the protection problems associated with devices such as very large nuclear reactors. Ultimately, the accumulated data will form a basis from which radiation barriers of the correct thickness and material may be designed for economical and safe protection.

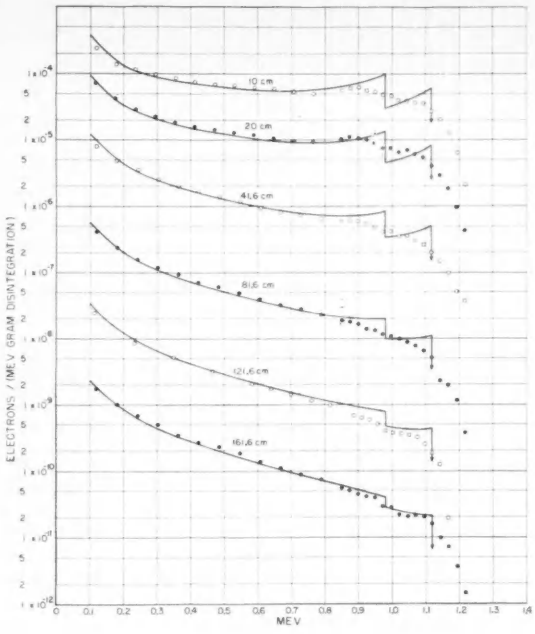
One series of experiments on the penetration characteristics of gamma-rays utilized a large tank of water to simulate effectively an infinite medium. Radioactive cobalt (Co^{60}) served as the source of gamma rays, and two experiments were conducted, one to determine the intensity, the other to determine the quality of the radiation at varying distances from the source. In the intensity experiment, conducted by Gladys White of the NBS staff, the Co^{60} source was suspended in the middle of a 60-foot water tank. The amount of energy dissipated in the medium was measured with an ionization chamber and a Geiger-Müller counter at increasing distances from the source. The data showed that the decrease in the total intensity of the radiations closely approached the trend predicted in theories previously developed by NBS.

Determination of the quality of the radiations was delayed for some time because of a lack of techniques for measuring the energy spectrum of secondary electrons. Recently, however, a new method, that of scintillation spectroscopy, has been adapted by Dr. Evans Hayward, also of the NBS staff, to determine the energy of fast-moving electrons generated by gamma-rays. This technique was employed at NBS to observe the quality of the radiations by measuring the scintillations they produced in an anthracene crystal. These observations, too, agreed very well with NBS theoretical predictions.

As gamma radiation penetrates matter, it interacts with the substance either through the photoelectric effect, Compton scattering, or pair production. The predominance of one effect over the others depends on the energy of the quanta and the atomic number of the penetrated material. The characteristics of the radiation can be predicted accurately only under conditions corresponding to an infinite space or volume, and measurements must be made with detectors that do not appreciably disturb any of the quantities being observed. In the NBS experiment to determine radiation quality, a large tank (12 by 12 by 25 feet) of water was used that satisfactorily simulated the conditions of an infinite medium. In addition, the atomic number and density of anthracene crystals are so close to those of water, that to the electrons as they are scattered in the crystal, there appears to be no transition from water to the crystal. Hence, the pulse-height distribution representing the energy lost in an anthracene crystal would correspond to the energy distribution of



Cross section (top) of the NBS experimental setup for determining the quality of gamma radiations from radioactive cobalt. A wooden platform was mounted over a large (12 by 12 by 25 foot) tank of water into which was suspended the source of gamma rays and a counter. Six Co^{60} sources were used at six different separations between the source and the counter. A cross section of the counter (below) shows its component parts. The whole unit is encased in a water-tight aluminum and plastic container.



The differential spectra of electrons produced by a Co^{60} source in an anthracene crystal as a function of the distance in water from the source. The ordinate scale is in terms of the number of electrons per Mev interval, per disintegration of the source, per gram of anthracene, and the abscissa scale, in Mev. The series of dots were obtained from the experimental data, and the solid curves from the predictions made in theories developed by NBS.

the electrons produced in an equal mass of water occupying the same position.

The Co^{60} source and a counting instrument were suspended near the center of the water tank from a wooden rack. The counter consisted of the anthracene crystal, a Lucite light pipe, a photomultiplier tube, and a preamplifier. The whole unit was enclosed in an aluminum and Lucite container to protect it from the surrounding water. The Lucite light pipe separated the crystal from the photomultiplier, and a thin aluminum foil wrapped around the Lucite served as a light reflector. Thus, as the electrons are produced in the anthracene crystal, the light they produce is guided down the Lucite tube and the scintillations are detected by the photomultiplier.

The counter was designed to measure the energy of only those electrons produced in and totally absorbed by the anthracene crystal. Tests were made to ascertain that only these electrons were detected. A negligible contribution to the measured energy distribution was made by all those electrons that were created outside but scattered into the crystal and those created inside and scattered outside the crystal. Additional checks were run to determine the sensitivity of the spectrum to the length of the Lucite light tube and to the presence of a second photomultiplier tube close to the crystal. In all instances, the effects were negligible.

The resolution of the counter was determined from the width of the internal conversion line of Cs^{137} (a source of a monochromatic radiation). A very weak Cs^{137} source was prepared, covered with a formvar film, and placed directly in contact with the crystal so that the beta spectrum and the electrons arising from the conversion of the photons within the atom could be observed. The pulse-height distribution resulting from the internal conversion line proved to be gaussian with a half width of 110 kev.

Six Co^{60} sources, ranging from 10^6 to 10^{11} disintegrations per second, were used at varying separations between the source and the detector. Different sources were used at each separation in order to have sufficiently low counting rates and thus avoid residual and accumulated effects from the very large number of low-energy electrons characteristic of these spectra. The relative intensities of the sources had been measured in pairs and compared to an NBS cobalt standard, by which specific activities are know within ± 6 percent.

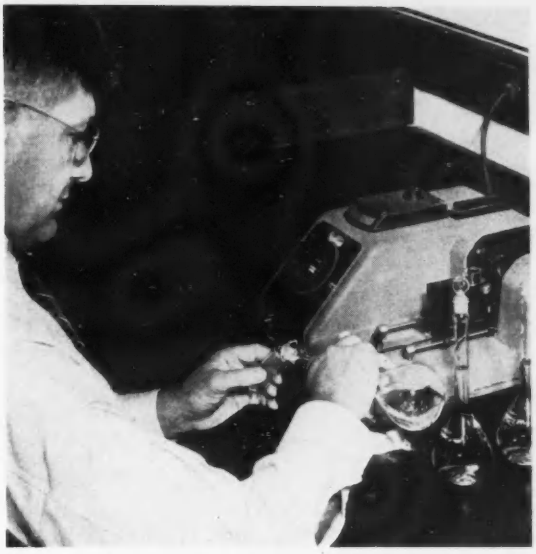
The electron spectra produced by 1.17- and 1.33-Mev Co^{60} gamma rays were measured at distances of 10, 20, 41.6, 81.6, 121.6, and 161.6 centimeters from the source. In plotting the data, the ordinate scale was in terms of the number of electrons per Mev interval, per disintegration of the source, per gram of anthracene, and the abscissa scale was in Mev. In order to express the data for the ordinate in these units, it was necessary to know not only the counting rate but also the disintegration rate of the source and the window width of the counting instrument. The error in measuring the absolute intensities was ± 10 percent, due mostly to uncertainties in the determination of the latter two quantities.

The energy scale for the abscissa was obtained by making a linear plot of the data and taking the two points of inflection at the end of the spectrum as corresponding to 0.96 and 1.12 Mev, the maximum energy Compton electrons that can result from the 1.17- and 1.33-Mev gamma rays. This calibration was accurate to about ± 1.5 percent. The standard deviations based on the number of counts were all less than ± 5 percent and almost all less than ± 3 percent. The background was negligible because the large mass of water provided an excellent shield for stray radiation.

At 10 centimeters from the source, the high-energy end of the spectrum is quite intense, and two peaks, corresponding to the two gamma rays, are easily recognized. At greater distances the energy loss becomes more and more concentrated in the lower-energy electrons, and the rate at which the spectrum changes becomes lessened. At distances of a meter or more, the changes in the shape of the spectrum of these medium and hard radiations are too small to be measured with this low-resolution spectrometer.

For further technical details, see The penetration and diffusion of Co^{60} gamma rays in water using spherical geometry, *Gladys R. White, Phys. Rev.* **80,** *154 (1950).*

Rapid Determination of Bismuth in Lead-Tin Alloys



A spectrophotometric method recently developed by the National Bureau of Standards makes possible more rapid and accurate testing of solders, type metals, and other lead-tin alloys. Here a yellow complex, formed by combination of the separated bismuth with thiourea, is added to one of the cells of the photometer for measurement of its absorbancy.

AN ACCURATE spectrophotometric method for the determination of bismuth in lead-base and tin-base alloys has been developed by B. B. Bendigo, R. K. Bell, and H. A. Bright of the National Bureau of Standards. Because of its rapidity and convenience, the new method appears to be ideally suited to the testing of solders, type metals, and other lead-tin alloys in industrial laboratories.

Bismuth is added to lead-tin alloys to lower their melting points. The presence of bismuth thus promotes tinning or spreading in solders; in type metals bismuth prevents contraction of the type face when it solidifies upon cooling. Greater additions of bismuth, along with cadmium and antimony, to the lead-tin alloys result in the low-melting "fusible" alloys used widely in safety devices.

Several methods have been in use for determining bismuth in lead-tin alloys. Some of these older methods, however, are rather lengthy, and most of them are limited as to the conditions under which they can be applied. To expedite the testing of Government purchases, a more rapid method, specifically designed for analysis of the commercial lead-tin alloys, was sought. The resulting procedure requires only 2 to 3 hours of the analyst's time and may be applied without limitation to any of the common lead-tin alloys.

In the NBS method, the sample is first dissolved in a mixture of hydrobromic acid and bromine. Perchloric acid is added, and tin, antimony, and arsenic are removed as the volatile bromides by heating the acid solution. Nitric acid is added, and bismuth in the residual solution is then precipitated as the oxychloride. The precipitate is dissolved in nitric acid, and the acidified bismuth solution is treated with thiourea to form a yellow complex. The optical absorbancy of the colored solution is measured with a filter photometer, and the amount of bismuth is read from an absorbancy curve previously prepared by treating known amounts of bismuth with thiourea.

Because the procedure isolates bismuth from other metals, which also form complexes with thiourea, all of the added thiourea is available for forming the bismuth complex. At NBS, the method showed an accuracy of ± 0.002 percent of bismuth for lead-base and tin-base alloys containing from 0.02 to 0.10 percent of the element.

For further technical details, see Spectrophotometric determination of bismuth in lead-base and tin-base alloys, *by Bruce B. Bendigo, Rosemond K. Bell, and Harry A. Bright, J. Research NBS* **47**, 252 (1952) *RP2250.*

Fire Tests of Concrete-Protected Steel Columns

A NEW Building Materials and Structures Report covers fire exposure tests made on four loaded, 6-inch steel H-columns protected by concretes made with siliceous aggregates. The tests were made in gas-fired furnaces equipped with hydraulic jacks for applying load. Loads to which the columns were subjected during the tests were those currently recommended by the American Institute of Steel Construction. Two of the columns had concrete coverings made with river gravel aggregates, and aggregates in the concrete coverings for the others were a crushed clear quartz and a crushed milky quartz. Information developed from

these tests supplements earlier data obtained at the Underwriter's Laboratory in Chicago and the former Pittsburgh testing station of the Bureau.

As the concrete aggregates similar to those used in the tests can be obtained almost anywhere, they are constituents of much of the commercially available concretes. The steel columns tested were of the type usually employed in buildings.

Fire endurance limits for the columns are given as well as a formula for the calculation of the fire resistance of structural steel columns. The publication also describes the materials, column constructions, and testing equipment and, by means of diagrams, graphs, and halftones, illustrates the manner of conducting the tests and securing the results.

National Bureau of Standards Building Materials and Structures Report 124, *Fire tests of steel columns protected with siliceous aggregate concrete*, by Nolan D. Mitchell, 12 pages, 2 tables, 14 illustrations, 15 cents (order from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.).

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards, volume **48,** number 3, March 1952 (RP2301 to 2311, incl.).

Technical News Bulletin, volume **36,** number 3, March 1952, 10 cents.

CRPL–D91. Basic Radio Propagation Predictions for June 1952. Three months in advance. Issued March 1952. 10 cents.

Research Papers

Reprints from Journal of Research, volume 48, No. 2, February 1952

RP2291. Film-rupture mechanism of stress corrosion. Hugh L. Logan.

RP2292. A note on the bounds of the real parts of the characteristic roots of a matrix. P. Stein.

RP2293. Chart for the TE_{11} mode piston attenuator. Charles M. Allred.

RP2294. Table of the zeros and weight factors of the first twenty Hermit polynomials. Herbert E. Salzer, Ruth Zucker, and Ruth Capuano.

RP2295. Film dosimetry of electrons in the energy range 0.5 to 1.4 million electron volts. J. Fleeman and F. S. Frantz, Jr.

RP2296. Thermal converters as AC-DC transfer standards for current and voltage measurements at audio frequencies. Francis L. Hermach.

RP2297. Some nonnegative trigonometric polynomials connected with a problem in probability. Eugene Lukacs and Otto Szasz.

RP2298. Measurement of cesium-137 and cobalt-60 gamma radiation with a pressure ionization chamber. G. R. Grove.

RP2299. Techniques for growing and mounting small single crystals of refractory compounds. Fred Ordway.

RP2300. Crystal forms of chromium orthophosphate. Barbara M. Sullivan and Howard F. McMurdie.

Building Materials and Structures

BMS129. Fire resistance of shutters for moving-stairway openings. Noland D. Mitchell, Edward D. Bender, and James V. Ryan. 10 cents.

Circulars

C510. Tables of chemical kinetics: Homogeneous reactions. $4.00.

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